SECTION 5.3 DIURNAL AND RESTING LOSS EMISSIONS

5.3.1 Introduction

While most hydrocarbons are emitted from the tailpipe of vehicles as the product of incomplete combustion, a significant amount of hydrocarbons emanate through evaporation, namely, hot soak, diurnal, resting and running loss emissions. Diurnal and resting loss emissions occur as a result of the vehicle's fuel heating and volatilizing as the ambient temperature rises or declines during the day. To reduce evaporative hydrocarbon emissions, vehicles are equipped with a canister containing activated charcoal to adsorb the vapors. When the vehicle is operated, the canister is purged with ambient air and the stored hydrocarbon is burned in the engine.

The diurnal emission factors in MVEI7g1.0c were developed in 1992 using data from Air Resources Board's past In-Use Vehicle Surveillance programs as well as Inspection and Maintenance projects. The diurnal basic emission rates were estimated by measuring hydrocarbon vapor from a vehicle during a compressed one-hour Sealed Housing Evaporative Determination (SHED) test. During this test, a heating blanket is placed in contact with the vehicle's fuel tank to heat the fuel from 60 to 84 F over a one-hour period, representing a temperature excursion that stationary vehicles may experience daily. The resting loss basic emission rates were based on limited 3-day and 8-day diurnal test data (SAE 901110).

Although the above methods attempt to quantify diurnal and resting loss emissions, the compressed nature of the test may not faithfully reproduce the real-time evaporative emission process and may, therefore, underestimate emissions. In other words, the one-hour condensed diurnal test may not generate the total diurnal and resting loss emissions from a 24-hour diurnal. Thus, there is a critical need to model diurnal and resting loss emissions using real-time data to improve the emissions inventory. In this study, diurnal and resting loss results were analyzed from four databases: ATL(A096-214 and A132-183), CRC and EPA. All data were collected under real-time conditions ranging from 24 hours to 72 hours with different combinations of fuel and temperature cycle. Additionally, the temperature profiles are for the ambient SHED temperature rather than the tank temperature (with a heating blanket).

5.3.2 Objectives

This analysis has the following objectives:

1. To develop the diurnal and resting loss basic emission rates as a function of ambient temperature and fuel RVP.
2. To develop the fuel and temperature correction factors.
3. To develop the multi-day correction factors for diurnal and resting loss emissions

4. To define evaporative emission regimes (normal, moderate, and liquid leaker) and develop regime growth rates for CARB and FI vehicles.

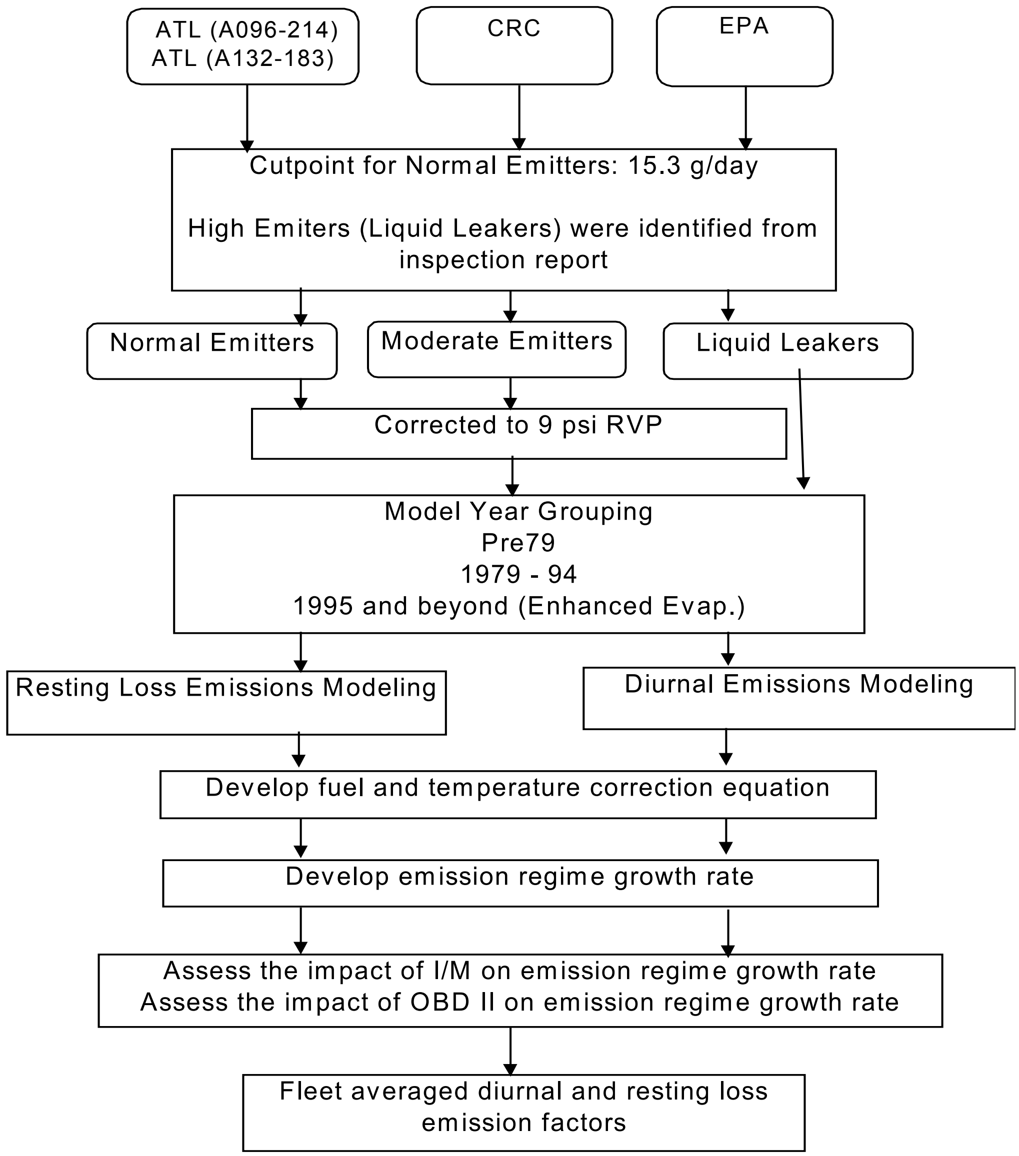


Figure 5.3-1. Flowchart of the methodology used in data analysis of diurna and resting loss emissions.

5.3.3 <u>Methodology</u>

Figure 5.3-1 outlines the methodology used for the analysis of diurnal and resting loss emissions. The four databases were combined into one. The resulting data are shown in Table 5.3-1a - 291 vehicles covering passenger cars and trucks with model years ranging from 1971 to 1995.

Table 5.3-1a. Distribution of vehicles' model years from four databases.

ATL096-214 (n=10)

Vehicle Type	Car	
Model Year	CARB	FI
73	1	0
76	1	0
78	1	0
79	1	0
83	1	0
85	1	0
86	0	1
87	0	1
90	0	2
Subtotal	6	4

ATL132-183 (n=11)

Vehicle Type	Car	
Model Year	CARB	FI
73	1	0
76	1	0
78	1	0
83	1	0
84	1	0
85	1	0
86	0	1
87	0	1
89	0	1
90	0	2
Subtotal	6	5

Combined Databases (n=291)

Vehicle Typ	Car		Truck	
Model Year	CARB	FI	CARB	FI
71	2	0	2	0
72	6	0	1	0
73	6	0	3	0
74	6	0	1	0
75	3	0	2	0
76	14	0	2	0
77	8	0	4	0
78	2	0	0	0
79	2	0	0	0
80	2	0	3	0
81	3	0	7	0
82	0	0	7	0
83	4	0	7	0
84	3	1	13	1
85	6	8	15	2
86	2	13	3	4
87	3	15	4	5
88	2	5	0	12
89	1	7	0	14
90	0	12	0	8
91	0	11	0	7
92	0	4	0	0
93	0	6	0	3
94	0	3	0	0
95	0	0	0	1
Total	75	85	74	57

CRC (n=151)

Vehicle Typ	Car		Truck	
Model Year	CARB	FI	CARB	FI
71	2	0	1	0
72	6	0	1	0
73	4	0	3	0
74	4	0	1	0
75	3	0	1	0
76	11	0	2	0
77	8	0	4	0
78	0	0	0	0
79	0	0	0	0
80	0	0	2	0
81	0	0	5	0
82	0	0	6	0
83	0	0	7	0
84	0	0	12	1
85	0	0	15	2
86	0	0	3	4
87	0	0	4	3
88	0	0	0	9
89	0	0	0	12
90	0	0	0	8
91	0	0	0	7
Subtotal	38	0	67	46

EPA (n=119)

Vehicle Typ	Car		Truck	
Model Year	CARB	FI	CARB	FI
71	0	0	1	0
72	0	0	0	0
73	0	0	0	0
74	2	0	0	0
75	0	0	1	0
76	1	0	0	0
77	0	0	0	0
78	0	0	0	0
79	1	0	0	0
80	2	0	1	0
81	3	0	2	0
82	0	0	1	0
83	2	0	0	0
84	2	1	1	0
85	4	8	0	0
86	2	11	0	0
87	3	13	0	2
88	2	5	0	3
89	1	6	0	2
90	0	8	0	0
91	0	11	0	0
92	0	4	0	0
93	0	6	0	3
94	0	3	0	0
95	0	0	0	1
Subtotal	25	76	7	11

Table 5.3-1b summarizes the fuel RVP and temperature cycles used in each database. With the exception of the CRC test program, most vehicles were tested over different temperature cycles using different fuels.

All vehicles were segregated into three emission regimes, namely; normal, moderate and liquid leakers. A liquid leaker was defined as a vehicle classified by its emission rate as a liquid leaker when undergoing visual inspection. Note that most of the liquid leakers were identified from the CRC study, which included a detailed inspection report on the condition of each vehicle.

Table 5.3-1b. Distribution of diurnal tests from four databases.

ATL096-214 (n=30)

Vehicle Type	Car	
RVP	9 psi	
Temp Range	CARB	FI
60 - 84 F	12	8
65 - 105 F	8	2

ATL132-183 (n=40)

Vehicle Type	Car							
RVP	6.6 psi		7.5 psi (ethanol)		7.6 psi		8.7 psi	
Temp Range	CARB	FI	CARB	FI	CARB	FI	CARB	FI
65 - 105 F	6	5	2	4	7	5	6	5

CRC (n=151)

Vehicle Type	Car		Truck	
RVP	6.8 psi		6.8 psi	
Temp Range	CARB	FI	CARB	FI
72 - 96 F	38	0	67	46

EPA (n=560)

Vehicle Type	Car							
RVP	6.3 psi		6.7 psi		6.9 psi		9.0 psi	
Temp Range	CARB	FI	CARB	FI	CARB	FI	CARB	FI
60 - 84 F	0	6	0	0	12	43	19	65
72 - 96 F	0	6	12	29	12	44	19	64
82 - 106 F	0	6	7	18	12	45	13	49

(cont'd)

Vehicle Type	Truck					
RVP	6.3 psi		6.9 psi		9.0 psi	
Temp Range	CARB	FI	CARB	FI	CARB	FI
60 - 84 F	0	0	0	2	7	11
72 - 96 F	7	9	0	2	7	11
82 - 106 F	8	9	0	2	0	4

Prior to establishing a cutpoint for normal and moderate emitters, a correlation equation was developed relating the one-hour condensed diurnal and the 24-hour real-time diurnal test (see Appendix 5.3-1). To be consistent with the cutpoint used in the hot soak analysis, the same 2 g/test (based on the one-hour condensed diurnal test) was selected to distinguish normal and moderate emitters. According to the correlation equation mentioned earlier, 2 g/test (one-hour) corresponds to 15.3 g/day. Therefore, vehicles were divided into normal and moderate emitters based on this 15.3 g/day cutpoint.

The domain of the database is described below:

- Fuel RVP (6.3 psi, 7.0 psi, 7.5 psi, 9.0 psi)
- Temperature cycles (60 – 84 F, 65 – 105 F, 72 – 96 F, and 82 – 106 F)
- Vehicle Types (Passenger Car and Light Duty Truck)
- Model Year Range (1971 to 1995)
- Fuel Delivery System (CARB, TBI, and PFI)
- Emission Status (Normal, Moderate and Liquid Leakers)

Since not all data were collected under the same temperature cycle and fuel RVP, the data were adjusted to a common RVP prior to analysis. To do so, the hourly average emissions were computed combining all temperature cycles at each fuel RVP (6.3 RVP, 7.0 RVP, 7.5 RVP and 9.0 RVP). The hourly average emissions were then normalized (treating the data at 9 RVP as unity). As a result, all hourly average emissions of various fuel RVPs were standardized to 9 RVP (liquid leakers are not assumed to be effected by RVP).

Model year grouping were based on the same model year split used in the hot soak analysis. Duncan's test was performed on the data and it was found that no statistical difference exists between: (1) car and truck and (2) TBI and PFI. As a result, car and truck were combined into a single category, and TBI and PFI data were combined into a single category, called Fuel Injection (FI).

Finally, the data were stratified into several categories according to emission status (normal, moderate and liquid leakers), fuel delivery system (FI and CARB), and model year group (Pre-79, 1979-94, and 1995 and beyond). Hourly average emissions were then computed for each stratum. (See Appendix 5.3-2.)

5.3.4 <u>Diurnal and Resting Loss Basic Emission Rates</u>

Diurnal emissions are defined as the evaporative emissions occuring when the ambient temperature rises. Figure 5.3-2a shows an example of how temperature cycle relates to hourly average emissions for a particular category (normal emitter, FI, and 1979-1994). As seen in this figure, hourly average emissions rise as the ambient temperature increases. Only the data corresponding to a rising ambient temperature were used for the diurnal emission analysis. In other words, the hourly average emissions from the four temperature cycles were used to develop a model using the ambient temperature as the independent variable. Several regression models were tried and it was concluded that a third order polynomial equation fit the data adequately.

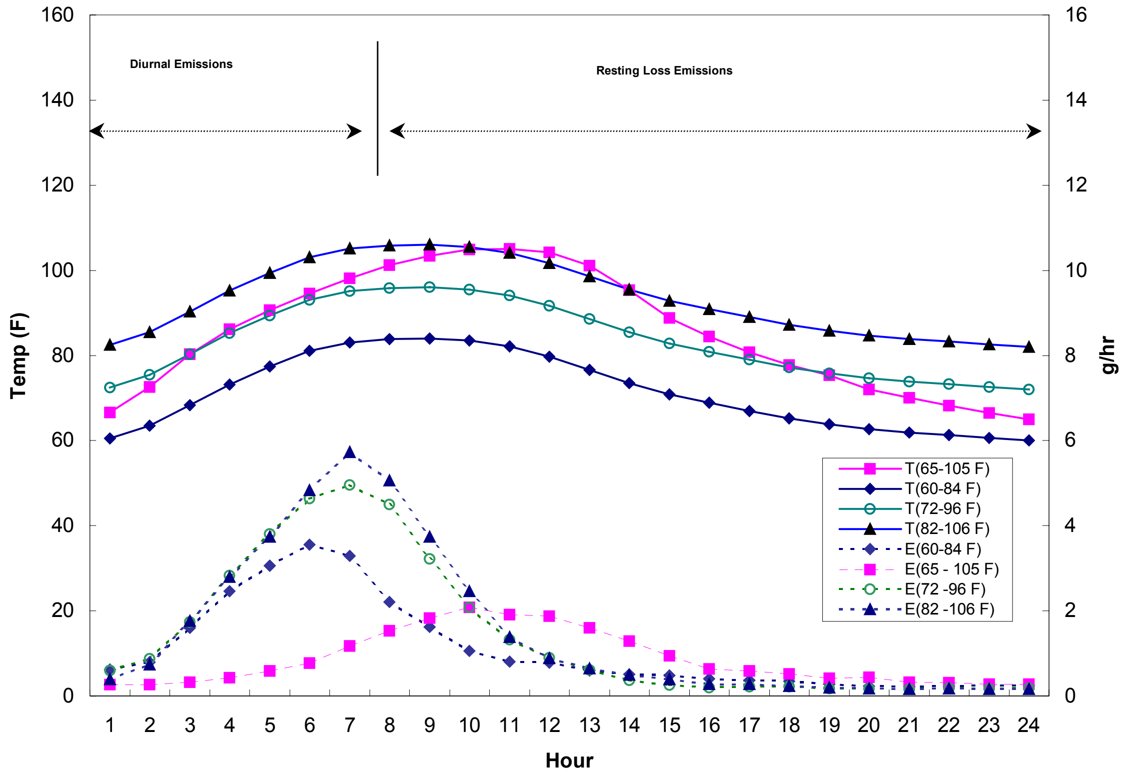


Figure 5.3-2a. Average hourly emission for the category: moderate emitters/FI/model year 1979-94.
T - Temperature E - Emissions

Resting loss emissions are defined as the evaporative emissions occuring when the ambient temperature (T) declines or remains constant. Only the data corresponding to the declining ambient temperature were used in the modeling of resting loss. Similar to diurnal emission, a third order polynomial equation was used. The general form of this polynomial equation is listed below._

$$\text{Diurnal or Resting Loss (g/hr)} = \alpha(T) + \beta(T)^2 + \chi(T)^3 + \text{Intercept} \qquad (5.3\text{-}1)$$

For normal and liquid leakers, it was assumed that diurnal or resting loss emissions rates increase from 55 F to 110 F and that diurnal and resting loss emissions fall to zero at 55 F or below. While a third order equation was used to predict diurnal and resting loss emission rates reasonably for the temperature range between 65 F to 110 F, a linear model was used to depict the emission rates between 55 F and 65 F for diurnal and resting loss. For liquid leaker, it was assumed that the diurnal and resting loss emissions rates increase from 40 F to 110 F. A third order equation was used to predict the diurnal and resting loss emission rates between 70 to 110 F and a linear model was used to depict the emission rates from 70 F to 40 F. Table 5.3-2a and 5.3-2b list the coefficients of the regression models for diurnal and resting loss emissions for the temperature ranges described above. Any diurnal or resting loss at a different fuel RVP should be adjusted by fuel and temperature correction factors

Table 5.3-2a Coefficients of the regression model for diurnal and evaporative emissions (fuel RVP = 9 psi)*.

Diurnal Evaporative Emission (g/hr)

Status	System	MY Group	Intercept	Temp	$Temp^2$	$Temp^3$	Conditions	Tech Group
Normal	CARB	Pre77	0.3702	-0.0220910	0.0003170		Ranges from 65 F to 110 F	1-3, 21, 22
	CARB	77+	1.3300	-0.0495310	0.0004930		Ranges from 65 F to 110 F	4,23,24
	FI	79-94	-3.6979	0.1310920	-0.0015340	0.0000066	Ranges from 65 F to 110 F	5-12, 25-32
	FI	Enhanced	-0.4230	0.0149969	-0.0001755	0.0000007	Ranges from 65 F to 110 F	13, 33
	FI	Zero Evap	-0.1058	0.0037492	-0.0000439	0.0000002	Ranges from 65 F to 110 F	14, 34
Moderate	CARB	Pre77	-65.1714	2.5978250	-0.0346650	0.0001590	Ranges from 65 F to 110 F	1-3, 21, 22
	CARB	77+	-40.4512	1.5929020	-0.0208880	0.0000952	Ranges from 65 F to 110 F	4,23,24
	FI	79-94	11.4632	-0.3342420	0.0026300		Ranges from 65 F to 110 F	5-12, 25-32
	FI	Enhanced	1.3114	-0.0382	0.0003009		Ranges from 65 F to 110 F	13, 33
	FI	Zero Evap	0.3278	-0.0096	0.0000752		Ranges from 65 F to 110 F	14, 34
High	All	All	25.0075	-0.6909750	0.0054520		Ranges from 70 F to 110 F	All

Resting Evaporative Emission (g/hr)

Status	System	MY Group	Intercept	Temp	$Temp^2$	$Temp^3$	Conditions	Tech Group
Normal	CARB	Pre77	2.6605	-0.0864800	0.0007370		Ranges from 65 F to 110 F	1-3, 21, 22
	CARB	77+	2.8687	-0.0870240	0.0006820		Ranges from 65 F to 110 F	4,23,24
	FI	79+	1.5166	-0.0459490	0.0003580		Ranges from 65 F to 110 F	5-12, 25-32
	FI	Enhanced	0.1735	-0.0052566	0.0000410		Ranges from 65 F to 110 F	13, 33
	FI	Zero Evap	0.0434	-0.0013141	0.0000102		Ranges from 65 F to 110 F	14, 34
Moderate	CARB	Pre77	8.0181	-0.2481270	0.0020160		Ranges from 65 F to 110 F	1-3, 21, 22
	CARB	77+	-37.7714	1.5544770	-0.0211460	0.0000960	Ranges from 65 F to 110 F	4,23,24
	FI	79+	-9.9635	0.4569720	-0.0070080	0.0000361	Ranges from 65 F to 110 F	5-12, 25-32
	FI	Enhanced	-1.1398	0.0522776	-0.0008017	0.0000041	Ranges from 65 F to 110 F	13, 33
	FI	Zero Evap	-0.2850	0.0130694	-0.0002004	0.0000010	Ranges from 65 F to 110 F	14, 34
High	All	All	16.9159	-0.4379580	0.0033520		Ranges from 70 F to 110 F	All

*The model is defined as:
Emission (g/hr) $= a*T + b*T^2 + c*T^3 +$ intercept

Table 5.3-2b. Coefficients of the linear model for diurnal and evaporative emissions (fuel RVP = 9 psi)*.

Diurnal Evaporative Emission (g/hr)					
Status	System	MY Group	Temp	Conditions	Tech Group
Normal	CARB	Pre77	0.02736	Ranges from 65 F to 55 F	1-3, 21, 22
	CARB	77+	0.01934	Ranges from 65 F to 110 F	4,23,24
	FI	79+	0.01413	Ranges from 65 F to 110 F	5-12, 25-32
	FI	Enhanced	0.00162	Ranges from 65 F to 110 F	13, 33
	FI	Zero Evap	0.00040	Ranges from 65 F to 110 F	14, 34
Moderate	CARB	Pre77	0.08930	Ranges from 65 F to 55 F	1-3, 21, 22
	CARB	77+	0.09818	Ranges from 65 F to 55 F	4,23,24
	FI	79+	0.08493	Ranges from 65 F to 55 F	5-12, 25-32
	FI	Enhanced	0.00972	Ranges from 65 F to 55 F	13, 33
	FI	Zero Evap	0.00243	Ranges from 65 F to 55 F	14, 34
High	All	All	0.11180	Ranges from 70 F to 40 F	All

Resting Evaporative Emission (g/hr)					
Status	System	MY Group	Temp	Conditions	Tech Group
Normal	CARB	Pre77	0.01531	Ranges from 65 F to 55 F	1-3, 21, 22
	CARB	77+	0.00936	Ranges from 65 F to 55 F	4,23,24
	FI	79-94	0.00424	Ranges from 65 F to 55 F	5-12, 25-32
	FI	Enhanced	0.00049	Ranges from 65 F to 55 F	13, 33
	FI	Zero Evap	0.00012	Ranges from 65 F to 55 F	14, 34
Moderate	CARB	Pre77	0.04075	Ranges from 65 F to 55 F	1-3, 21, 22
	CARB	77+	0.03046	Ranges from 65 F to 55 F	4,23,24
	FI	79-94	0.00341	Ranges from 65 F to 55 F	5-12, 25-32
	FI	Enhanced	0.00039	Ranges from 65 F to 55 F	13, 33
	FI	Zero Evap	0.00010	Ranges from 65 F to 55 F	14, 34
High**	All	All	0.08945	Ranges from 70 F to 40 F	All

*The linear model for normal and moderate emitters is defined as:
Emission (g/hr) = a* (T-55)

** The linear model for high emitters is defined as:
Emission (g/hr) = a* (T-40)

Figure 5.3-2b presents the estimated diurnal emissions for both moderate and normal emitters. As expected, the emission rates are higher for older vehicles. Figure 5.3-2c shows the estimated resting loss for both moderate and normal emitters. A similar trend showing higher emission rates for older vehicles was also observed. When comparing Figure 5.3-2b with 5.3-2c, it was found that the magnitude of emissions from the diurnal is higher than resting loss. Figure 5.3-2d shows the diurnal and resting losses for the liquid leakers. As expected, the liquid leaker has the highest hourly diurnal and resting loss emissions.

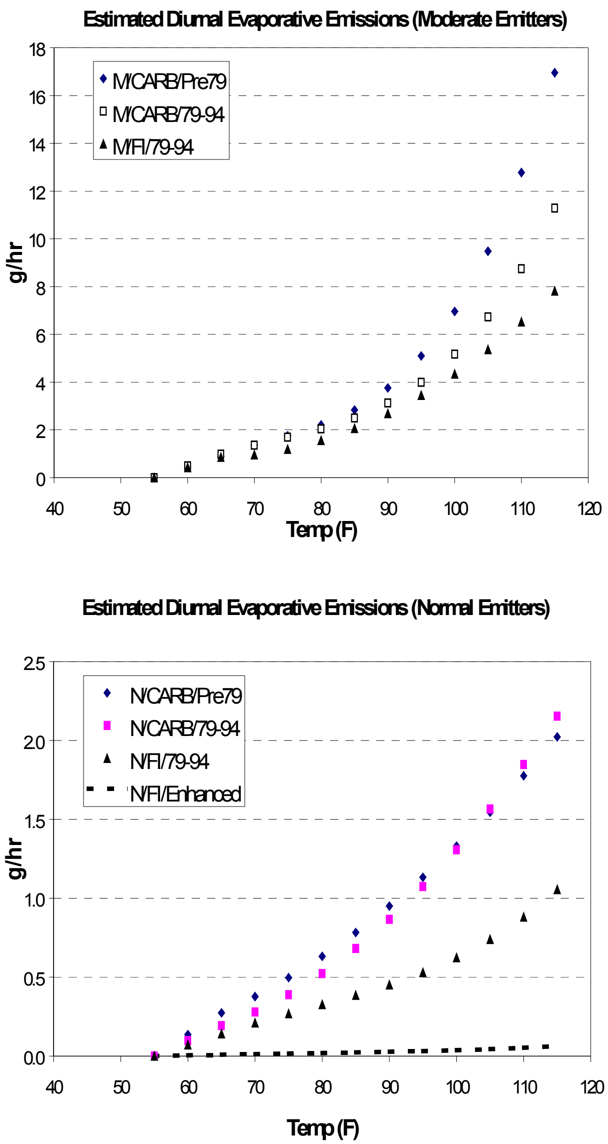


Figure x-2b. Relationship between estimated diurnal emissions and ambient temperature for normal and moderate emitters.

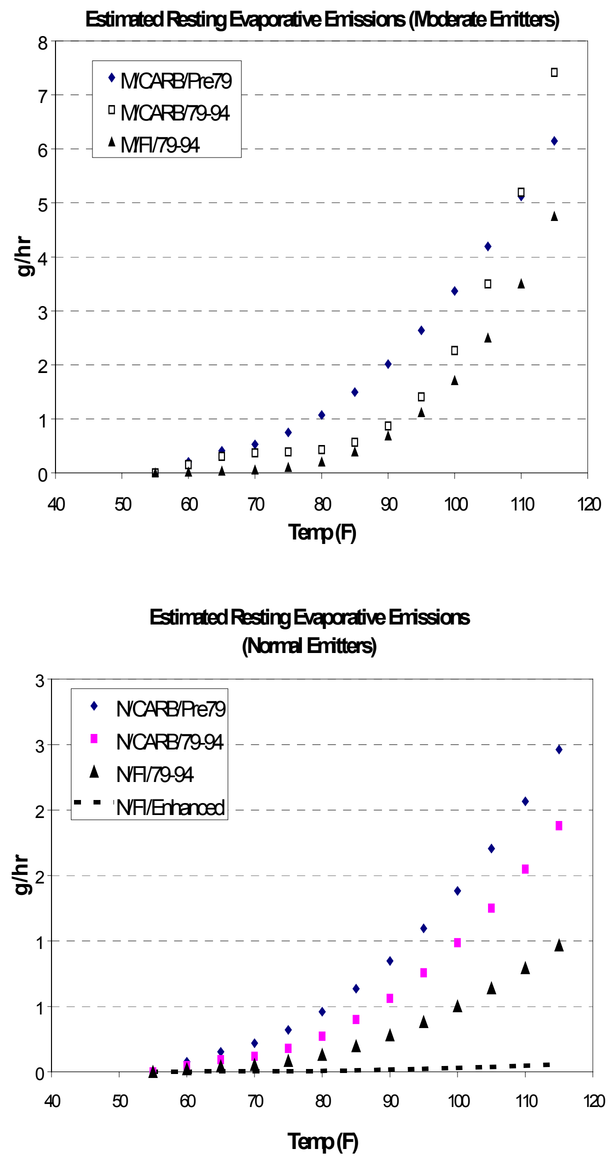


Figure x-2c. Relationship between estimated resting loss emissions and ambient temperature for moderate and normal emitters.

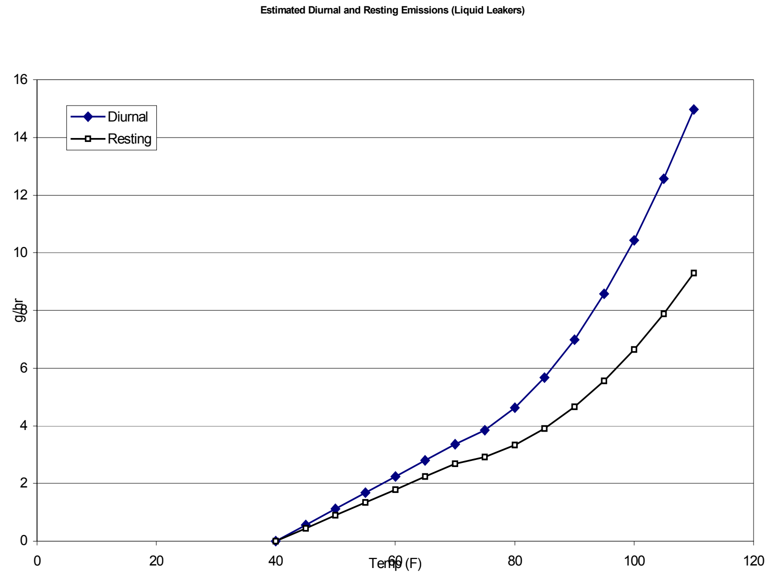


Figure 5.3-2d. Estimated diurnal and resting loss emissions with respect to ambient te
for liquid leakers

5.3.5 <u>Basic Emission Rate for model year 1995 and beyond (Enhanced Evaporative Emission Standards)</u>

The enhanced evaporative emission standards for passenger cars and trucks is 2 gram/test (based upon a three-day diurnal and a one-hour hot soak test), with the temperature ranging from 65 F to 105 F. Four enhanced evap vehicles were analyzed from CRC Project E-41, Real World Evaporative Testing of Late Model In-Use Vehicles, McClement, Hall and Strunck, October 1999. The mean emissions of these four vehicles are assumed to be representative of Normal emitting enhanced evap vehicles. To derive temperature based BERs for diurnal and resting losses for model years 1995+, diurnal and resting loss emission rates from the category (Normal/FI/ 79-94) were used as a basis for estimation. The BERs for the Normal/79-94 groups were reduced iteratively until the sum of the daily emissions equaled the mean emissions observed in E-41. The data from E-41 and the adjustment algorithm are given in Appendix 5.3-3.

5.3.6 <u>Estimation of Basic Emission Rate for Near-zero Evap Vehicles</u>

The basic emission rates for near-zero evap vehicles were estimated from the basic emission rates of enhanced evap vehicles. Similar to the methodology used to estimate BERs for enhanced evap vehicles, near-zero evap vehicles were assumed to emit like enhanced evap vehicles, but with emissions reduced by the ratio of the standards. For PCs, the ratio is 0.5/2.0= 0.25. The BERs for vehicle classes other than passenger vehicles were determined using the ratio of the standards (relative to PCs) as outlined below. These ratios are applied to Normal and Moderate emitters only.

Class Specific Scaling Factor

Class	Tech	Near-zero Evap Standards	Scalar (Ratio of Standards)
PC	Near-zero Evap	0.5	1
T1	Near-zero Evap	0.65	1.3
T2	Near-zero Evap	0.9	1.8
T3	Near-zero Evap	1	2
T4	Near-zero Evap	1	2
T5	Near-zero Evap	1	2
T6	Near-zero Evap	1	2
T7	Near-zero Evap	1	2
T8	Near-zero Evap	1	2

Phase-in Schedule

Near-zero evap vehicles are phased in as follows:

MY	% Near-zero
2004	40
2005	80
2006	100

5.3.7 <u>Temperature and Fuel Correction Factor</u>

The purpose of developing temperature and fuel correction factors is to adjust diurnal and resting loss emission factors to other fuel and temperature conditions. Diurnal or resting loss emissions tend to increase when the ambient temperature is higher. Likewise, diurnal or resting loss will rise if fuel RVP increases. To detect such a relationship, it is necessary to analyze a sample of vehicles undergoing the same temperature cycle at different fuel RVP levels.

The data used in this portion of the analysis is a subset of the EPA database. This subset contains 8 CARB and 18 FI vehicles that were tested over the 72-96 F temperature cycle both at 7 and 9 RVP. Hourly HC averages were computed for the temperature range between 72 to 96 F. As a result, we are able to discern the relationship of temperature and fuel RVP. Because of the small sample size, both CARB and FI vehicles were combined for the data analysis. Finally, a regression model was developed to depict the relationship as listed below.

$$f(T, RVP) = \alpha(T+15) + \beta(RVP) + \chi(T+15)(RVP) + \text{Intercept} \qquad (5.3\text{-}2)$$

where the domain of temperature (T) ranges from 55 to 110 F and RVP ranges from 6.5 to 13 psi.

Therefore, the temperature and fuel correction factor

= f(T, RVP)/f(T, 9 RVP)

Table 5.3-3 lists the coefficients of the above equation and Figure 3 graphically presents the temperature and fuel correction equation. As expected, emissions rise as temperature or RVP increases. The temperature and fuel correction factor is applicable to normals and moderates in FI and CARB categories.

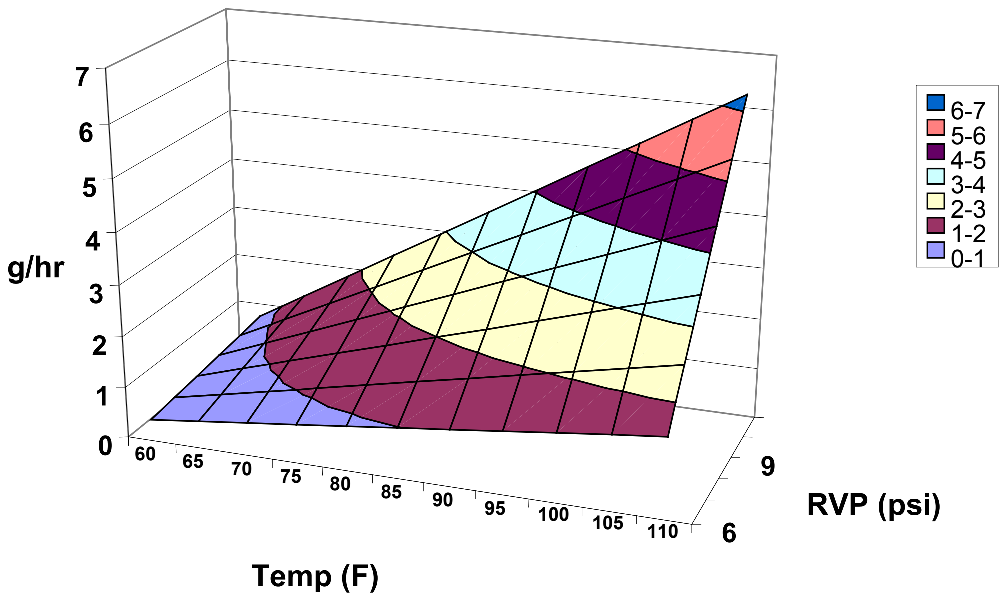


Figure 5.3-3. Relationship between ambient temperature and fuel RVP on diurnal and resting evaporative loss

Table 5.3-3. Coefficient for Temperature and Fuel Correction Equation

TEMP	FUEL	TEMPFUEL	INTERCEPT
A	B	C	D
-0.0822	-1.2507	0.0175	6.2152

f (T, RVP) = A*(T+15) + B*RVP + C*(T+15)*RVP + D (g/hr)

Temperature and Fuel Correction Factor = f(T, RVP)/f(T, 9)

where T and RVP ranges from 55 F to 110 F and 6.5 to 13 RVP respectively.

5.3.8 <u>Multi-day Correction Factors</u>

Cumulative emissions of HC may be different for day 2 and day 3 of vehicle soak. Therefore, there is a need to develop a correction factor to account for the changes in total emissions for day 2 as well as day 3 and beyond.

The data used for the multi-day correction factor analysis contains 101 vehicles tested at 9 psi over 72 hours. These vehicles were also tested over different temperature cycles; namely, 60 – 84 F, 65 – 105 F, 72 – 96 F, and 82 –106 F.

To develop multi-day correction factors, an analysis was performed to compare the cumulative HC emissions over 24 hours, 48 hours, and 72 hours, respectively. It was found that the temperature cycle has a minimal effect on the relative changes of cumulative HC emissions for day 1, day 2 and day 3 for both CARB and FI vehicles. In other words, there were no relative changes in cumulative HC for day 1, day 2, and day 3 when compared with various temperature cycles. Based upon certification data on low emitting data, it is assumed that near-zero evap vehicles will not have elevated emissions on the second and subsequent days.

On the other hand, the fuel-metering system appears to have a major impact on the multi-day correction factor. As shown in Figure 5.3-4, the hourly average emissions for CARB vehicles remain almost constant throughout three days whereas hourly average emissions for FI vehicles increase daily. Table 5.3-4 lists the multi-day correction factor for CARB and FI. Diurnal or resting loss for day 2 as well as day 3 and beyond can be estimated by multiplying the multi-day correction factor by the basic emission rates of day 1.

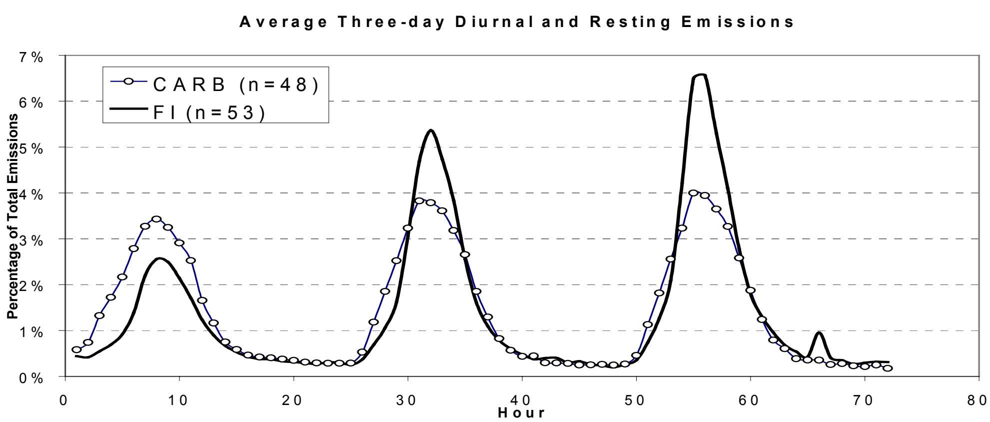


Figure 5.3-4. Normalized average three-day diurnal and resting evaporative loss based on 101 veicles at 9 psi RVP

Table 5.3-4. Multiple day Correction Factors at 9 psi RVP

System	Day 1	Day 2	Day 3 +
CARB	1	1.01	1.01
FI	1	1.53	1.86
Enhanced	1	1.00	1.00
Near Zero	1	1.00	1.00

5.3.9 <u>Regime Growth Rates</u>

The emission regime growth rates for CARB and FI were developed from the historical Air Resources Board condensed one-hour diurnal data, using 2g/test as the cutpoint for normal and moderate categories. For consistency, it was assumed that the EPA's assessment of the fraction of liquid leakers could be used for both CARB and FI vehicles.

Figure 5.3-5a and 5b present the regime growth rates of normal, moderate and liquid leakers for CARB and FI, respectively. The equations describing the regime growth pattern were also listed. As expected, CARB vehicles tend to attain moderate and liquid leaker categories faster than FI vehicles. Moreover, the percentage of liquid leakers for CARB is higher than FI, for any given age. In the event that the sum of fractions exceed 100%, the regimes are normalized.

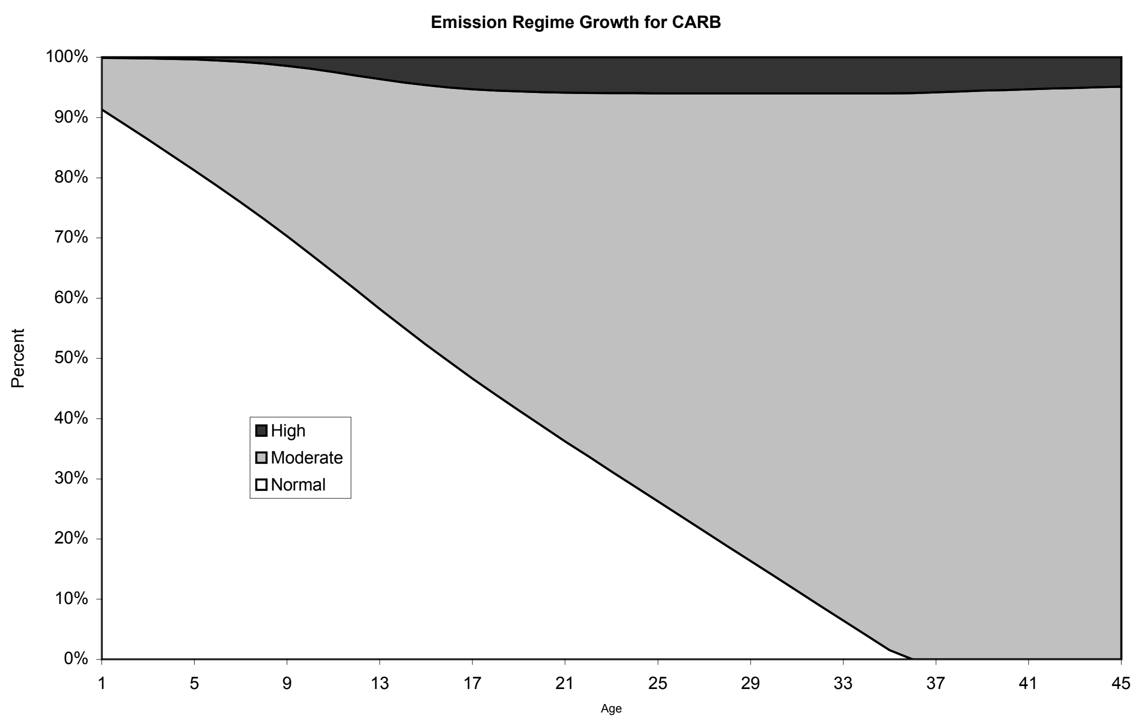


Figure 5.3-5a. Regime growth of normal, moderate, liquid leakers for CARB vehicles.

CARB	Equation
Normal	Fraction = 0.92 + -0.0259*Age
Moderate	Fraction = 0.085521 + 0.02468*(Age -1)
LL	Fraction = 0.06/(1+120*exp(-0.4*age))

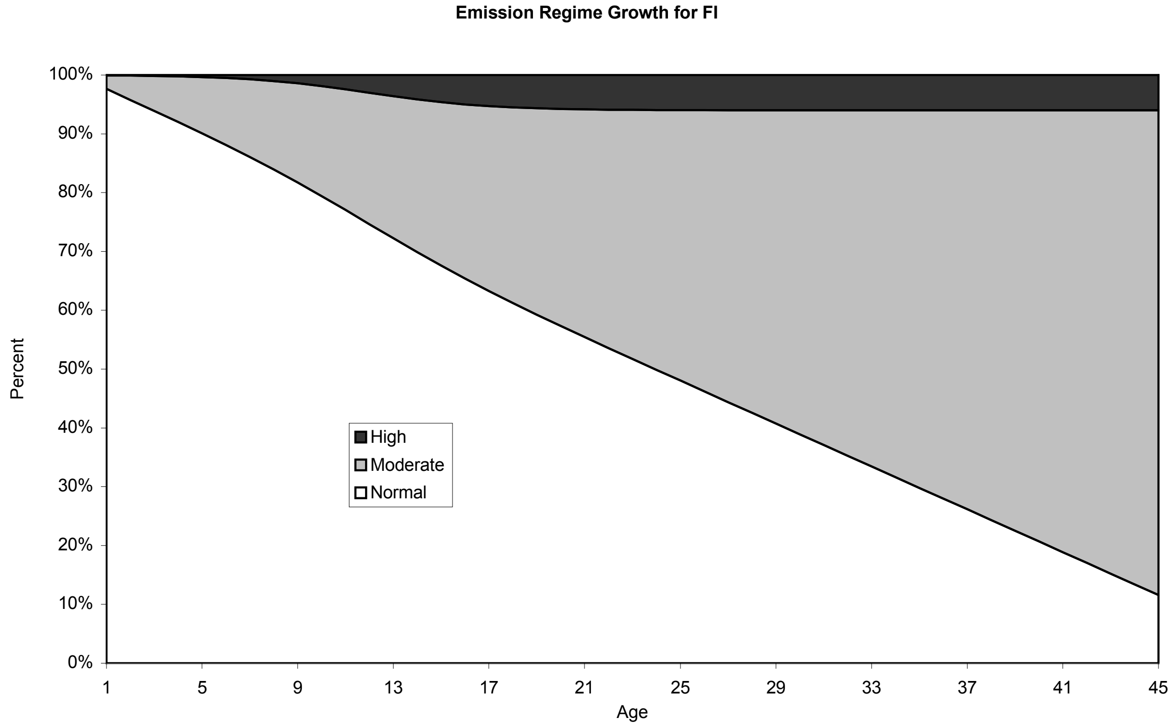


Figure 5.3-5b. Regime growth rate of normal, moderate, and liquid leakers for FI vehicles.

FI	Equation
Normal	Fraction = 0.975 + -0.0189*Age
Moderate	Fraction =0.0229 + 0.01821*(Age-1)
LL	Fraction = 0.06/(1+120*exp(-0.4*age))

As discussed in section 5.1, the growth of liquid leaking enhanced and near-zero fleets are assumed to be half of the FI growth rate.

5.3.10 I/M corrected Diurnal and Resting Loss Emission Factors

The California I/M program requires vehicles to undergo inspection biennially. Hence, we assume moderates will receive I/M benefit as some of the components causing high evaporative emissions are identified and repaired.

The average emission factor for normal emitters with respect to age is defined as follows:

Average EF for Normal Emitters in the Fleet ($EF_{\text{Ave Normal Emitters, Age}}$)
= Normal Emitter Growth Rate $_{CARB}$ *EF_{CARB}*CARB Vehicle Fraction +
Normal Emitter Growth Rate $_{FI}$*EF_{FI}*FI Vehicle Fraction
(5.3-3)

Similarly, the average emission factor for moderate emitters with respect to age is defined as follows:

Average EF for Moderate Emitters in the Fleet ($EF_{\text{Ave Moderate Emitters, Age}}$)
= Moderate Emitter Growth Rate $_{CARB}$ *EF_{CARB}*CARB Vehicle Fraction +
Moderate Emitter Growth Rate $_{FI}$*EF_{FI}*FI Vehicle Fraction
(5.3-4)

Average EF for Liquid Leakers in the Fleet ($EF_{Ave\ LL,\ Age}$)
= Liquid Leaker Growth Rate $_{CARB}$ *EF $_{CARB}$*CARB Vehicle Fraction +
Liquid Leaker Growth Rate $_{FI}$*EF $_{FI}$*FI Vehicle Fraction (5.3-5)

Because of the I/M program, there is an emission benefit for moderate emitters. In particular, vehicles subject to I//M and successful repair will change their status from moderate to normal emitters. Therefore, the moderate emitter growth rate for CARB and FI is adjusted accordingly.

Gas cap failure rates were well documented in a 1996 smog check study conducted by BAR. Therefore, gas cap failure rates were used to estimate the emission control failure rate in I/M. (See Appendix 5.3-4 for the methodology to estimate gas cap failure rate.)

It was assumed that the vehicles in the moderate emitter regime benefit from the I/M program. Specifically, vehicles in the moderate emitter category are identified and repaired, and will move to the normal emitter regime after repair. However, vehicles in the liquid leaker category were assumed not to be identified by I/M and thus will not change its emission regime size.

Fraction of moderate emitters moved to normal emitters per inspection period (Rate $_{Moderate\ to\ Normal}$)

= Identification Rate (ID %)*Incremental Gas Cap Failure Rate (IGC Fail)*Repair Efficiency (Repair %) (5.3-6)

Thus, adjusted moderate emitter growth rate for both CARB and FI per inspection period is as follows:
= Moderate Emitter Growth Rate - Rate $_{Moderate\ to\ Normal}$
(5.3-7)

Assuming the identification rate and repair efficiency is 95%, the new moderate emitter growth rate is thus given as follows:

New Moderate Emitter Growth Rate =
Moderate Emitter Growth Rate * (1- 0.95*gas cap failure rate) (5.3-8)

5.3.11 Moderate Emitter Growth Rate and OBDII

Because of the OBD II system, emissions control components are closely monitored and likely to be repaired once malfunctioning components are detected. Therefore, OBDII vehicles will be modeled by suppressing the formation of moderate emitters for the first seven years of a vehicle's life. As a result, the new moderate emitter growth rate for OBDII vehicles will be created by subtracting the fraction of moderate emitters for the first seven years, as presented below:

The adjusted moderate emitter regime growth

$$= 0.0229 + 0.01821*(Age-1) - 0.13216$$
$$= 0.01821*(Age-1) - 0.10916 \qquad (5.3\text{-}9)$$

Note that if the fraction of moderate emitters becomes negative, it is considered zero. It was assumed that the regime growth rate for liquid leakers would remain unchanged as listed in Figure 5.3-5b. Therefore, the fraction of normal emitters is given as follows:

Fraction of Normal Emitters =
1 – Adjusted Fraction of Moderate Emitters – Fraction of Liquid Leakers

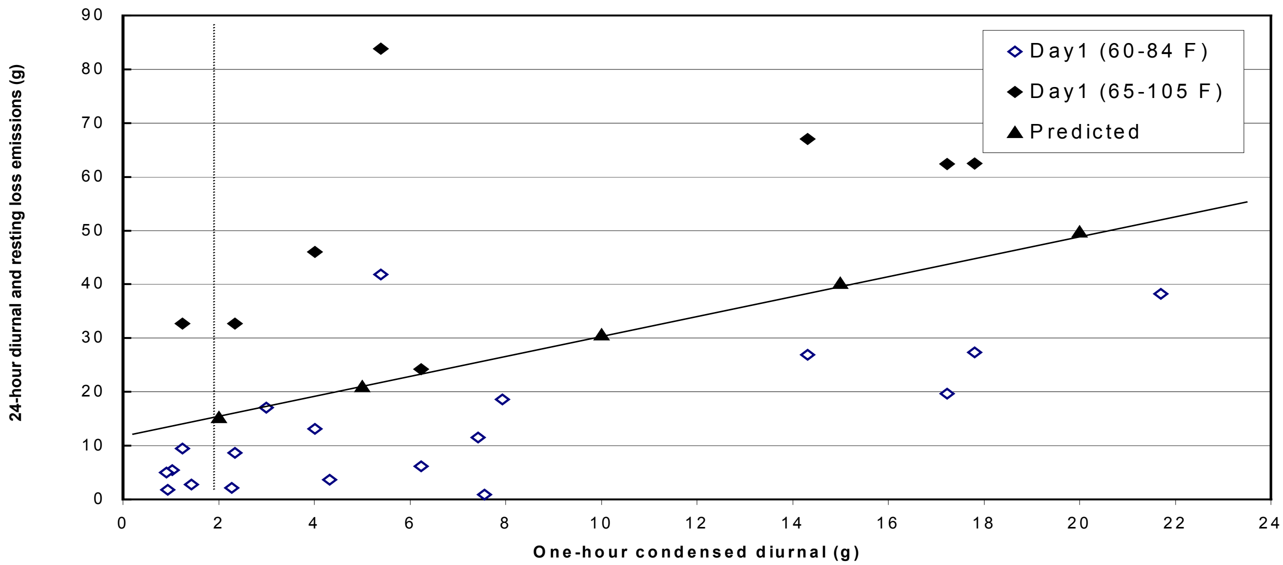
5.3.12 Conclusions

While this study attempts to model both diurnal and resting loss using ambient temperature as the driving force, there are limitations in modeling because of lack of data. Both diurnal and resting losses were modeled based on a defined temperature cycle; however, these cycles may not faithfully depict the temperature profile experienced by vehicles under various initial conditions. Furthermore, with the more stringent evaporative emission standards, newer vehicles are expected to have less evaporative emission. Diurnal and resting loss emission data from vehicles subject to the enhanced evaporative emission standards are needed.

Future studies should focus on the following issues:

(1) Vehicles of model year 1995 and beyond;
(2) The effect of time and initial temperature on diurnal and resting loss;
(3) Understanding the lag time between the peaks of emissions and ambient temperature;
(4) The impact of solar loading and wind on evaporative emissions; and
(5) Comparing the diurnal and resting loss emissions with the methodology used by the EPA.

Appendix 5.3-1. Correlation between one-hour condensed diurnal and the 24-hour test (9 psi RVP)



Correlation Equation:

24-hour test(g) = 11.4335 + 1.9195*(One-hour condensed diurnal)

The purpose of this analysis is to relate the one-hour condensed diurnal test to the diurnal and resting loss emissions over a 24-hour period. Thus, the corresponding 24-hour cutpoint can be estimated from the 2 g/hr one-hour condensed diurnal test, similar to the cutpoint used in the hot soak analysis. The data used in this correlation analysis came from the a study conducted by Automotive Testing Laboratories in 1994 (Contract No. A096-214). The conventional one-hour hot soak results were compared with 24-hour test data. There were two diurnal temperature profiles; namely, 60 to 84 F and 65 to 105 F. As expected, data from the temperature profile 65 to 105 F have a higher total emissions when compared to the 60 to 84 F profile. Nevertheless, the correlation is developed in order to estimate a cutpoint to distinguish between normal and moderate emitters.

Appendix 5.3-2. Hourly average emissions based on emission status, model year groupings, fuel delivery system, and temperature cycles.

Status	Normal			
MY Group	1979 - 1994			
System	CARB			
Number	25	4	58	8
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.188	0.575	0.232	0.388
2	0.218	0.557	0.245	0.437
3	0.318	0.657	0.399	0.543
4	0.428	0.729	0.598	0.855
5	0.551	0.726	0.851	1.053
6	0.750	0.810	1.123	1.275
7	0.858	0.875	1.348	1.536
8	0.837	1.024	1.286	1.406
9	0.721	0.954	1.063	1.391
10	0.638	1.110	0.843	0.901
11	0.513	0.999	0.615	0.886
12	0.425	0.765	0.470	0.672
13	0.380	0.575	0.410	0.602
14	0.274	0.449	0.332	0.410
15	0.209	0.290	0.275	0.307
16	0.163	0.175	0.189	0.265
17	0.151	0.107	0.184	0.252
18	0.132	0.076	0.170	0.211
19	0.127	0.095	0.149	0.187
20	0.112	0.095	0.136	0.246
21	0.115	0.039	0.118	0.150
22	0.098	0.085	0.124	0.193
23	0.104	0.037	0.116	0.190
24	0.105	0.038	0.121	0.200
Sum	8.856	12.960	11.850	14.766

Status	Normal			
MY Group	Pre79			
System	CARB			
Number	4	1	7	
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.325	0.210	0.364	
2	0.211	0.238	0.384	
3	0.358	0.267	0.532	
4	0.613	0.386	0.720	
5	0.679	0.490	0.931	
6	0.785	0.639	1.205	
7	0.820	0.833	1.530	
8	0.787	0.869	1.629	
9	0.774	1.044	1.466	
10	0.658	1.277	1.218	
11	0.505	1.273	0.951	
12	0.407	0.795	0.716	
13	0.334	0.755	0.651	
14	0.275	0.652	0.563	
15	0.330	0.425	0.537	
16	0.176	0.197	0.391	
17	0.217	0.183	0.417	
18	0.153	0.146	0.360	
19	0.166	0.135	0.366	
20	0.146	0.095	0.332	
21	0.102	0.088	0.294	
22	0.145	0.095	0.326	
23	0.141	0.026	0.306	
24	0.144	0.027	0.320	
Sum	9.707	12.456	17.694	

Status	Normal			
MY Group	1995 and beyond			
System	FI			
Number	1		2	1
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.050		0.080	0.090
2	0.040		0.079	0.112
3	0.040		0.091	0.144
4	0.060		0.109	0.203
5	0.080		0.145	0.256
6	0.090		0.166	0.314
7	0.100		0.215	0.365
8	0.100		0.220	0.347
9	0.100		0.207	0.293
10	0.100		0.193	0.254
11	0.110		0.155	0.156
12	0.090		0.144	0.152
13	0.080		0.126	0.111
14	0.070		0.107	0.105
15	0.060		0.091	0.081
16	0.050		0.059	0.071
17	0.050		0.073	0.067
18	0.040		0.059	0.047
19	0.040		0.054	0.057
20	0.040		0.048	0.047
21	0.030		0.049	0.049
22	0.030		0.050	0.060
23	0.030		0.043	0.046
24	0.030		0.044	0.048
Sum	1.590		2.540	3.080

Status	Normal			
MY Group	1979 - 1994			
System	FI			
Number	118	17	173	77
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.089	0.119	0.128	0.146
2	0.113	0.119	0.149	0.155
3	0.221	0.148	0.265	0.240
4	0.361	0.196	0.391	0.319
5	0.481	0.239	0.498	0.441
6	0.540	0.302	0.603	0.593
7	0.594	0.367	0.716	0.796
8	0.480	0.429	0.689	0.934
9	0.362	0.476	0.595	0.845
10	0.263	0.565	0.467	0.677
11	0.176	0.674	0.338	0.464
12	0.145	0.498	0.274	0.328
13	0.118	0.426	0.222	0.274
14	0.095	0.305	0.185	0.222
15	0.080	0.194	0.139	0.182
16	0.058	0.105	0.140	0.136
17	0.054	0.090	0.108	0.119
18	0.052	0.078	0.095	0.115
19	0.042	0.075	0.087	0.104
20	0.045	0.074	0.084	0.092
21	0.041	0.058	0.072	0.099
22	0.041	0.069	0.073	0.090
23	0.043	0.054	0.075	0.081
24	0.043	0.055	0.078	0.084
Sum	4.626	6.318	6.644	7.726

Appendix 5.3-2. (cont'd)

Status	Moderate			
MY Group	1979 - 1994			
System	CARB			
Number	11	11	32	23
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.705	0.681	0.795	0.960
2	0.825	0.961	0.924	1.193
3	1.639	1.866	1.583	2.119
4	2.509	2.839	2.285	3.277
5	3.162	3.636	3.164	4.589
6	3.689	4.517	4.031	6.239
7	3.703	5.203	4.404	6.984
8	3.046	5.350	4.005	6.355
9	2.282	5.825	3.100	4.701
10	1.614	5.497	2.144	3.209
11	1.133	4.279	1.469	2.062
12	0.823	3.159	0.995	1.382
13	0.703	2.196	0.869	1.014
14	0.630	1.582	0.680	0.789
15	0.480	1.240	0.551	0.647
16	0.357	0.652	0.429	0.433
17	0.353	0.661	0.381	0.439
18	0.341	0.667	0.339	0.392
19	0.276	0.602	0.306	0.333
20	0.263	0.436	0.290	0.318
21	0.252	0.286	0.274	0.245
22	0.237	0.339	0.226	0.253
23	0.211	0.295	0.246	0.233
24	0.214	0.302	0.253	0.240
Sum	30.316	56.572	34.036	48.015

Status	Moderate			
MY Group	Pre79			
System	CARB			
Number	11	15	31	7
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.545	0.694	0.534	0.774
2	0.740	0.883	2.292	0.896
3	1.387	1.702	3.007	1.793
4	1.802	2.068	3.865	3.449
5	2.010	2.820	4.921	6.107
6	2.351	3.474	6.371	9.154
7	2.473	4.572	7.242	10.738
8	2.426	5.251	6.797	9.482
9	2.196	5.649	5.356	6.360
10	1.840	5.303	4.323	4.079
11	1.507	4.503	2.894	2.434
12	0.996	2.860	2.305	1.736
13	0.784	1.651	2.135	1.256
14	0.673	0.980	1.743	0.850
15	0.565	0.659	1.512	0.646
16	0.433	0.498	1.176	0.471
17	0.398	0.359	1.286	0.405
18	0.393	0.364	1.213	0.442
19	0.388	0.320	1.105	0.300
20	0.341	0.263	1.041	0.303
21	0.335	0.225	0.942	0.309
22	0.277	0.206	0.979	0.238
23	0.320	0.202	0.930	0.229
24	0.324	0.204	0.973	0.237
Sum	26.534	48.463	68.335	62.278

Status	Moderate			
MY Group	1979 - 1994			
System	FI			
Number	13	2	36	55
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	0.682	0.320	0.620	0.378
2	0.829	0.318	0.901	0.711
3	1.660	0.380	1.821	1.708
4	2.539	0.504	3.029	2.748
5	3.192	0.706	4.143	3.711
6	3.679	0.918	5.069	4.820
7	3.440	1.441	5.403	5.700
8	2.294	1.905	4.879	5.053
9	1.731	2.233	3.454	3.702
10	1.160	2.525	2.197	2.450
11	0.900	2.207	1.349	1.381
12	0.886	2.133	0.894	0.876
13	0.677	1.800	0.602	0.637
14	0.574	1.519	0.336	0.488
15	0.552	1.085	0.239	0.388
16	0.451	0.729	0.179	0.279
17	0.418	0.650	0.200	0.273
18	0.389	0.576	0.206	0.224
19	0.313	0.447	0.154	0.194
20	0.258	0.486	0.156	0.173
21	0.252	0.332	0.152	0.161
22	0.258	0.349	0.173	0.169
23	0.270	0.282	0.166	0.162
24	0.273	0.292	0.171	0.165
Sum	28.830	27.015	36.987	36.630

Status	High			
MY Group	All			
System	All			
Number	2		35	2
Hour	60-84 F	65 - 105 F	72 -96 F	82 -106 F
1	2.895		0.814571	3.75
2	3.095		3.887198	4.35486
3	4.015		4.491217	6.260341
4	4.915		5.457016	8.39
5	5.695		6.350595	10.2956
6	6.275		7.772331	13.65382
7	6.35		8.755185	11.59731
8	6.185		8.919793	12.67754
9	5.5		7.698219	9.868606
10	5.075		6.860281	8.372663
11	4.805		5.127289	7.315992
12	4.52		4.342946	5.650222
13	3.635		4.175853	5.534259
14	3.13		3.764295	4.396585
15	2.86		3.547298	3.88593
16	2.785		2.836253	3.935036
17	2.735		3.121084	3.736441
18	2.625		3.101931	3.578129
19	2.53		2.844746	3.637486
20	2.54		2.763386	3.620701
21	2.675		2.563845	3.679369
22	2.535		2.659463	3.71264
23	2.505		2.494234	3.457857
24	2.505		2.607179	3.549976
Sum	92.385		106.956	148.911

Appendix 5.3-3 - Enhanced Evap Vehicle

CRC Project E-41
World Evaporative Testing of Late Model In-Use Vehicles

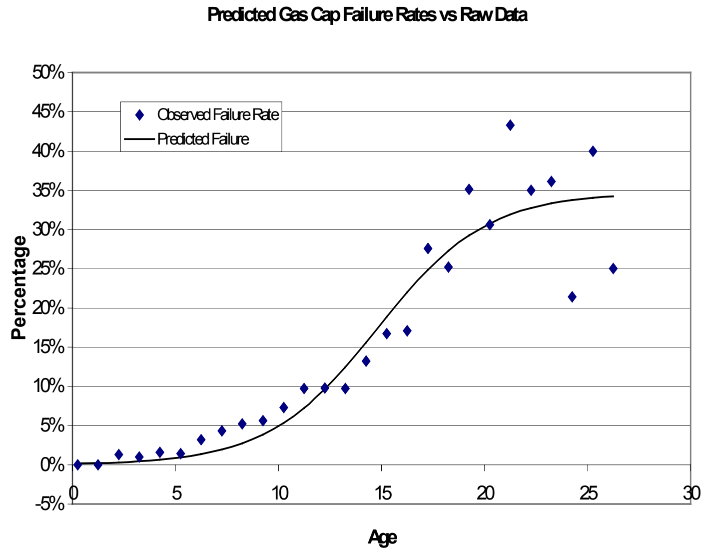
	Veh #	Yr./Make/Model	24-hour DHB Grams
enh	E-41008	1997 Dodge Stratus 2.4L, PFI, 16.0 tank	0.38
enh	E-41020	1997 Plymouth Breeze 2.0L, PFI, 16.0 tank	0.59
enh	E-41027	1996 Dodge Caravan 2.4L, PFI, 20.0 tank	0.82
enh	E-41032	1996 Chevrolet S-10 4.3L, PFI, 19.0 tank	0.35
		mean enh	0.54

Spreadsheet to calculate enhanced evap vehicle reduction

Hour	Temp profile	ER 9RVP N/79-94	RVPCF 9-->7 RVP	ER 7RVP N/79-94	E41 Enhanced	
1	65.0	0.1548	0.6962	0.1077	0.0123	
2	68.6	0.2075	0.6611	0.1372	0.0157	
3	72.3	0.2557	0.6386	0.1633	0.0187	
4	75.9	0.3011	0.6229	0.1876	0.0215	
5	79.5	0.3457	0.6113	0.2114	0.0242	
6	83.2	0.3914	0.6025	0.2358	0.0270	
7	86.8	0.4401	0.5955	0.2621	0.0300	
8	90.5	0.4937	0.5898	0.2912	0.0333	
9	94.1	0.5541	0.5851	0.3242	0.0371	
10	97.7	0.6232	0.5811	0.3621	0.0414	
11	101.4	0.7028	0.5777	0.4060	0.0465	
12	105.0	0.7950	0.5748	0.4570	0.0523	
13	101.7	0.5454	0.5775	0.3150	0.0360	
14	98.3	0.4599	0.5805	0.2670	0.0306	
15	95.0	0.3824	0.5840	0.2233	0.0256	
16	91.7	0.3128	0.5881	0.1840	0.0211	
17	88.3	0.2512	0.5930	0.1489	0.0170	
18	85.0	0.1975	0.5988	0.1182	0.0135	
19	81.7	0.1518	0.6059	0.0920	0.0105	
20	78.3	0.1140	0.6148	0.0701	0.0080	
21	75.0	0.0842	0.6264	0.0527	0.0060	
22	71.7	0.0623	0.6418	0.0400	0.0046	
23	68.3	0.0484	0.6635	0.0321	0.0037	
24	65.0	0.0425	0.6962	0.0296	0.0034	factor = enh/(79-94)
		7.9176		4.7185	0.5400	0.1144

Appendix 5.3-4 Estimation of the gas cap failure rate from BAR's smog check data performed in Spring 1996.

MY	Age	Observed Failure Rate	Predicted Failure
70	26.25	25.0%	34.2%
71	25.25	40.0%	34.0%
72	24.25	21.4%	33.7%
73	23.25	36.1%	33.3%
74	22.25	35.0%	32.7%
75	21.25	43.3%	31.9%
76	20.25	30.6%	30.7%
77	19.25	35.1%	29.2%
78	18.25	25.2%	27.3%
79	17.25	27.6%	24.8%
80	16.25	17.1%	22.0%
81	15.25	16.7%	18.8%
82	14.25	13.2%	15.6%
83	13.25	9.7%	12.4%
84	12.25	9.8%	9.6%
85	11.25	9.7%	7.2%
86	10.25	7.3%	5.3%
87	9.25	5.6%	3.8%
88	8.25	5.2%	2.7%
89	7.25	4.3%	1.9%
90	6.25	3.2%	1.3%
91	5.25	1.4%	0.9%
92	4.25	1.6%	0.6%
93	3.25	1.0%	0.4%
94	2.25	1.3%	0.3%
95	1.25	na	0.2%
96	0.25	na	0.1%



Parameter	Value
K	0.347
No	0.00133
R	0.3758

Model
Y= K/(1+((K-No)/No)*EXP(-R*AGE))